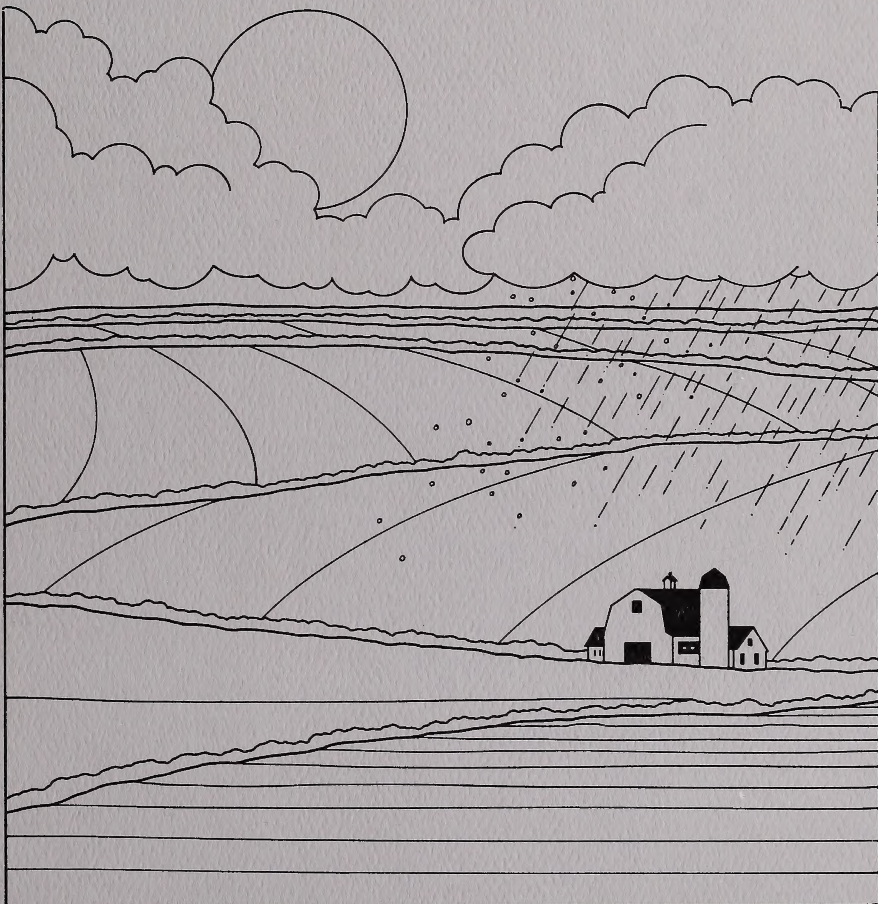
Agroclimatic Atlas of Alberta



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Introduction

This Agroclimatic Atlas brings together a variety of climatic information that is particularly relevant to agriculture. Although climatic information is available, it is not always readily accessible in a form that is suited to the needs of agriculture. The purpose of this publication is to present climatic information of importance to agriculture and to get the information into the hands of the agricultural community.

Climate in general

Weather and climate dictate what crops can be grown in a region and are mainly responsible for the yearly variation of yields. There is a difference between weather and climate: weather is the rain, sun, heat, cold or wind which happens now; climate is the long term average describing what generally happens.

Four factors determine climate

- position on the globe,
- wind systems,
- the ratio of water to land, and
- topography.

Latitude, how far north or south you are on the globe, has the biggest effect on climate. Both the intensity of the sun's radiation and wind circulation patterns change with latitude.

The sun's influence on climate is the most basic and the easiest to understand. Because of the spherical shape of the earth, the sun's rays heat the earth more at the equator than at the poles. Also significant is that the air above the earth's surface is heated by the earth's surface and not by the incoming radiation itself. The sun's radiation therefore heats land masses more than oceans, and equatorial regions more than polar regions. Large scale air circulation patterns prevent equatorial and polar regions from becoming progressively hotter and colder. The next two factors, wind systems, and the relationship of water to land also have an effect on each other.

The general wind circulation in the atmosphere results from nature's maintenance of the overall heat balance of the earth. As the large tropical and arctic air masses, which usually measure several hundreds of kilometres across, try to move north and south, the rotation of the earth deflects the wind. The result is a wide belt, covering the latitude of the Canadian Prairies, known as the zone of the westerlies, so-called because that is the direction from which the wind blows.

The interaction of the prevailing westerly winds with water, and its relation to land, in determining climate is demonstrated by the different climates of Canada's east and west coasts. The westerlies blow sea air onshore – mild air in winter and cool air in summer – to give British Columbia its moderate mild climate. In the Maritimes, the prevailing westerlies blow offshore, giving the east coast a more extreme climate and one more similar to that of inland Canada.

Oceans act as huge storage areas for heat. They absorb heat in spring and summer, then release it in fall and winter. The oceans also transmit heat and cold around the world in the form of great ocean currents such as the Japanese Current which brings warm water to the British Columbia and Alaska coasts or the Labrador current, which on Canada's east coast moves cold Arctic water southward. Such currents give adjacent land areas higher or lower temperatures than they would otherwise have. These currents help to account for the differences in climate of southern British Columbia and Newfoundland.

Topography is the final major factor influencing climate. In Alberta, this is a very significant factor. The Rocky Mountains force the air masses to rise and drop their moisture as precipitation creating wet conditions on the west side and drier conditions on the east side. Mountain ranges can also deflect the motion of air so that it moves parallel to the mountains. On a smaller scale, valleys have very different climates from surrounding level areas.

Climate is described by the average and extremes of the weather experienced. It is necessary to consider some of the major features of weather in Alberta to understand climate and its variability.

Weather is created by the movement and interaction of air masses. Air masses are huge bodies of air over hundreds of kilometres across, within which temperature and humidity change gradually. Their moisture content is determined by whether they are formed over an ocean or a continent. Temperature is controlled by the latitude of the air mass formation. The boundary between air masses with different properties is called a front. A cold front occurs when cold air advances towards warm air. It pushes under the warm air causing it to rise, cool and create precipitation. A warm front occurs when warm air overrides cold air, which can also cause precipitation. In general, there is more precipita-

tion over a larger region associated with a warm front than with a cold front. The passage of a cold front is, however, more likely to produce severe weather events including heavy rain, hail and tornadoes than the passage of a warm front.

Weather in Alberta

General

Weather in Alberta is produced by the interaction of air masses with differing temperature and moisture characteristics. The properties of these air masses differ with the season and with the area of formation, over land or sea and at what latitude.

In the winter, Alberta weather is dominated by the maritime polar and the continental polar air masses. The maritime polar air mass from the north Pacific is moist and provides the moisture for snow in the mountains and to a lesser extent over the prairie. The continental polar mass formed over mainland Canada is dry and cold. Occasional incursion of the Arctic air masses can create intense cold.

In the summer, Alberta weather is still dominated by the maritime and continental polar air masses, but maritime tropical air masses from both the Gulf of Mexico and from the Pacific can bring significant moisture into Alberta.

These air masses and the cold and warm fronts that they produce account for the daily precipitation and temperature under which agriculture must be conducted.

Precipitation and topography

A combination of moist air, a southeasterly wind and rising topography results in upslope precipitation. This type of precipitation is more prevalent in southern Alberta and its importance in providing moisture decreases to the north and east.

The greatest precipitation amounts occur in Alberta when moist air finds its way into the province from either the Gulf of Mexico or the southern Pacific (off California). This usually happens when a large low pressure system moves toward Alberta from the south. The southwesterly winds then push the moist air up against the rising land to the foothills. This enhances the precipitation process and leads to major widespread rain in the western prairies and eastern slopes of the Rocky Mountains.

The upslope conditions can create ground fogs a few thousand metres deep. This form of weather is so significant at Lethbridge that the instrument landing system at the Lethbridge airport is designed primarily to deal with it.

Convective precipitation

Convective storms or showers provide significant precipitation during the summer months, accounting for about 40 per cent of summer rainfall. The amount of rain produced by any shower can vary greatly. In some cases the rain evaporates before it reaches the ground, and in other cases it will be substantial as in the case of thunderstorms. The rainfall amount and its intensity can vary greatly over short distances. Heavy showers can produce both significant runoff and soil erosion.

The moisture source for convective storms is that moisture contained by the air mass and that evaporated from the earth's surface or transpired by vegetation. Summer thunderstorms are created by heating of the air in contact with the ground. This warm air rises and cools. If the lifting process continues long enough, precipitation will occur.

Topography can play a role in creating showers. Air must rise when it passes over rising ground, and this action increases cooling and encourages more precipitation. In Alberta, the Milk River Ridge, the Hand Hills and the Clear Hills have higher precipitation than surrounding areas.

Chinook winds

Chinook winds are a significant feature of Alberta's weather and have a major impact on the province's climate. They occur along the east slope of the Rocky Mountains throughout the province but the impact is most noticed in the southwest corner of the province. In Figure 1, Longley shows the number of days in December, January and February with maximum temperatures of 5°C or greater. The area within the 20 day line is the region that is generally considered the Chinook zone.

The warm, dry wind that descends on the leeward side of the Rocky Mountains is called the Chinook, which is the Indian Nation word meaning "Snow Eater". Rapid temperature changes of 25°C or more within a few hours are possible during winter Chinooks.

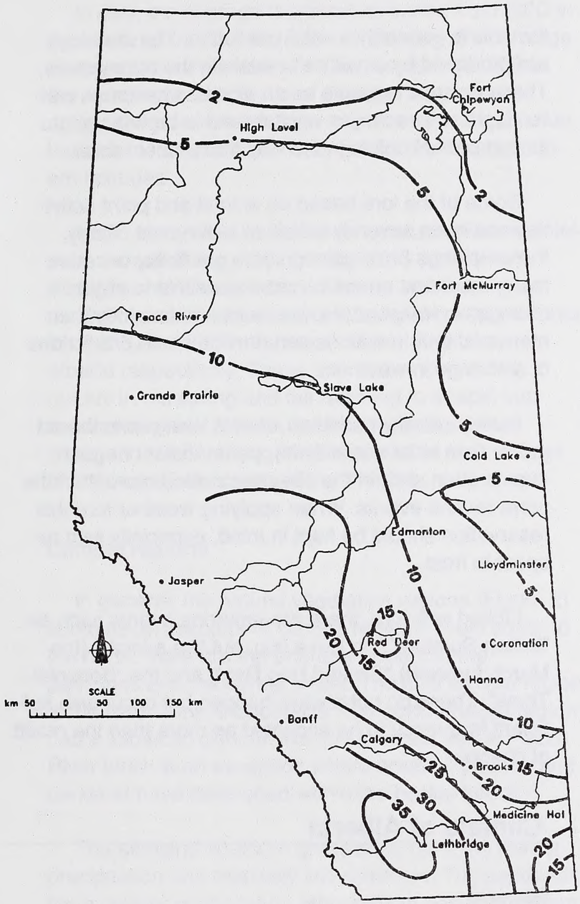

Figure 1. Average number of winter days with a temperature of 5°C or greater

The Chinook is important to Alberta because it moderates the effect of cold Arctic air. The effect is most significant in southern Alberta, where the warm wind frequently removes the snow cover during the winter. Farther from the mountains, this warm air may only raise the air temperature near the ground by a few degrees.

The strong gusty Chinook wind can be unpleasant, and can result in physiological and psychological reactions in humans such as headaches and increased irritability. Agriculture is affected since the high evaporation associated with Chinooks increases plant water stress in an area that already has low precipitation. However, the reduced snow cover produced by the Chinook lengthens the grazing season and decreases the amount of feed storage required.

The atmospheric processes that produce a Chinook act year round, but the effects of this process are most pronounced during the winter months. The Chinooks are the result of a westerly flow of air over the Rocky Mountains. The mountains create standing waves in the air which continue out over the prairie region. These waves have crests and troughs, as in a flowing stream. Where a wave trough reaches the ground, the temperature change is rapid while nearby areas may be relatively unaffected. The wave does not always reach the ground and the warm air can be flowing over cold air laying below it. When this occurs an intense temperature inversion is created which traps the cool air below and can, in an urban environment, result in high levels of air pollution. The wave motion of the Chinook also accounts for the familiar Chinook arch, which often extends for a considerable distance along the Rocky Mountains. The clouds in this arch form at the crest of the Chinook wave.

The conditions required for a Chinook are a high pressure system in western British Columbia and a low pressure in the lee of the Rocky Mountains. The strength of the Chinook depends on the moisture content of the air that flows between the high and low pressure systems, the pressure differences between the two systems and the topography of the affected area.

As the moist air passes over the mountains it is forced to rise resulting in precipitation on the western side of the mountains. The precipitation dries the air. Dry air heats up faster than wet air as it descends the eastern side of the Rocky Mountains. Dry air heats up at the rate of about 1°C for each drop of 100 metres.

Severe weather

Severe weather events occur in Alberta and can cause significant problems for agriculture. These severe events are produced by unstable atmospheric conditions and include hail storms, heavy rains, wind gusts, high winds and tornadoes. In the case of heavy rain, the risks to agriculture may be located at some distance from the storm itself because heavy rains in the top-reaches of a watershed can produce downstream flooding.

In general, severe weather events affect a few people greatly at any one time. These conditions cannot be prevented and efforts are currently underway to improve prediction and to provide advance warning permitting safeguards to prevent loss of life and property. Insurance (general and crop) provides some protection from this kind of loss.

Extreme weather

Extreme weather, unlike severe weather, is produced by stable atmospheric conditions. It can also create significant problems for agriculture. Examples of extreme weather include heat waves, cold spells, drought and wet periods.

In general, extreme weather affects a large number of people over a broad area in the province. Stable atmospheric conditions, such as a stationary high pressure ridge over British Columbia can be predicted and its effect, a lack of rainfall, projected. Protection against such events can be planned in some cases, but in other cases it is impossible. With stock watering supplies, it is possible to estimate need and construct adequate water storage to prevent shortage, but at a cost. In dryland farming, the summerfallow rotation is an effort to reduce the effect of inadequate rainfall. Insurance plans, such as crop or forage insurance, are an important way to reduce the financial risks and consequences of extreme weather.

Weather lore

Weather lore is based on both fact and fiction. It is often passed on from generation to generation even if circumstances have changed. The lore is often contained in a catchy rhyme:

"An evening grey and morning red
Will send a shepherd wet to bed"

This statement tested for London, England proved right 70 per cent of the time. This piece of lore has a sound scientific base. Weather systems approach from the west and are often preceded first by high thin cloud, then increasingly thick clouds at lower altitudes. This accounts for the grey at sunset. In the morning, the red at sunrise is caused by the long path the sunlight takes through the atmosphere and indicates no clouds to the east. The normal dusty atmosphere allows the sun's red rays to pass through to a greater extent than the blue rays; thus making the sky appear red.

Generally weather and climate lore must be applied in the environment for which they were developed. For example, in southwestern Alberta, the presence of a Chinook arch usually results in warm and windy conditions. A similar appearing cloud elsewhere will not foretell of this event. Some weather lore is linked with recurring events which have general applications. Over 2000 years ago, the Greeks recognized that sun haloes (sun dogs) foretold rain. Modern day studies confirm that this is generally a valid prediction. The sun dogs are produced by small ice crystals in the atmosphere. These crystals increase as an air mass becomes wetter. Light strikes the ice crystals and is broken up into its component colors in the way that a prism does.

Some of the lore based on animal and plant activities has been severely criticized in the past. Today, these sayings have gained some credibility because many creatures are much more sensitive to slight changes in temperature, pressure and humidity than man, and their reactions can provide some predictions of a change in weather.

Lore is usually based on what is best remembered rather than what normally happens. Violent or rare events often stick in the observer's mind more than the mere routine events. When applying weather lore this reservation should be kept in mind, especially with respect to frost.

Linked with lore, there are recurring events such as "Indian Summer", "In like a lion, out like a lamb" (the March forecast),"Ground Hog Day", and the "Bonspiel Thaw". These do not always happen but occur with sufficient frequency to be accepted as more than the result of chance.

Climate of Alberta

General

Alberta has a continental climate with warm summers and cold winters. The Rocky Mountains block the movement of moist Pacific air into the region, but allow the inflow of cold Arctic air masses. Alberta has a semiarid climate because the annual precipitation is less than the water evaporated by natural vegetation and agricultural crops. The distribution of temperatures and precipitation in Alberta results from the shifting boundary between the two dominant air masses. The air masses found over Alberta are either of continental or maritime origin. The air masses most commonly found are the maritime polar, continental polar, maritime tropical, and continental arctic. Usually only two of these air masses will be found over the province. As the fronts between the air masses shift north and south across Alberta, temperature changes rapidly. The boundary between the two air masses will usually be in the extreme north of the province in the summer and somewhere across the central part of the province in the winter.

In July, the average temperature varies from 20°C in the south to 14 °C in the north. In January, the average temperature varies from -24°C in the north to -9°C in the southwest. The range of average temperature across the province in winter is greater than in summer because of the reduced heating from the sun at northern latitudes.

Arctic air masses in the winter produce extreme minimum temperatures varying from -60°C in northern Alberta to -42°C in southern Alberta. In the summer, continental air masses produce maximum temperatures from 30°C to 42°C in the mountains and southern Alberta respectively. These air masses can move quickly in the spring and fall resulting in a rapid seasonal change. In Alberta, besides a north to south change in temperature, there is a west to east change of temperature because of the Chinook.

Climate regions

In general, the natural vegetation regions (Figure 2) serve as an indicator of climate regions. From south to the north, there are the prairie grasslands, the parklands and the boreal forest. The final climate region is the mountains and foothills. The northernmost region has a subarctic climate. The area known as the Peace River block is an exception where areas of prairies and parkland have developed within the boreal forest.

The semiarid southern grasslands have the lowest precipitation and relatively hot summers. The parklands have greater precipitation amounts but cooler summers and colder winters. The boreal forest region has the most precipitation but the shortest season with the lowest daytime temperatures.

The Peace River area within the boreal climate has warm summer temperatures for that latitude, quite low precipitation and a relatively short growing season. The agricultural potential is improved substantially by the long summer day length. Winters are long and cold.

The subarctic region generally north of the 59° latitude is colder with short cool summers and a greater incidence of severe winter temperatures.

The mountains and foothills can be separated for purposes of agricultural climate because of the extreme variation in amounts of precipitation and temperatures that occur over short distances in response to elevation. These areas also have short growing seasons, again with wide variation over a short distance because of rapid elevation changes.

Figure 2. Climate regions of Alberta

Farm climate

The climate averages provided by this atlas are based on the weather data collected at many sites. The climate on any farm or any field may differ from that of the area around it.

Topography, for example, has a marked effect on the incidence of frost. After sunset, the ground cools rapidly and its temperature soon drops below that of the air in contact with it. The layer of air immediately above the ground cools, becomes heavier and tends to drain down the land slope and collect in depressions and hollows. In these frost pockets, this cold air drainage results in much later frost in the spring and earlier frosts in the fall than found in surrounding areas.

Hillside locations, on the average will have longer frost free periods than locations on lower ground or in a valley. Night winds have a large influence on temperature during clear nights. Conditions for cold air drainage exist when there is no general air movement. Even a light wind will mix the relatively warm air above the thin cold surface layer. Moderate winds will quickly equalize temperature.

South and west facing slopes receive more direct radiation and tend to be warmer than east and north facing slopes. These effects can be either positive or negative depending on crop type and soil moisture.

Farm management may itself have a slight effect on conditions. Maintaining stubble and trash to catch snow may reduce surface soil temperature slightly in the spring. The trash intercepts some heat and wet soil warms up more slowly than dry soil, but the value of the added moisture for crop production and decreased hazards of wind and water erosion more than compensates for the slight decrease in soil temperatures.

Microclimate

The microclimate of any small area exhibits climate conditions that are distinct from the surrounding area. The characteristics of the surface, whether it is bare or covered with vegetation, have a great influence on the microclimate. A sheltered area has a different microclimate than an open field. Generally warmer daytime temperatures are found in river valleys. Two examples are along the Peace River at Dunvegan and at the town of Peace River where vegetables thrive. Cooler areas are found at higher elevations, such as the tops of the Cypress and Hand Hills.

Collection of weather and climate data

Data collection

In Alberta, two types of weather observation programs exist. The first is the twenty-two synoptic stations (Map 1) operated by the Atmospheric Environment Service. Detailed observations of weather conditions are reported hourly and provide the bulk of the information used in weather forecasting.

The second type is the climate station where volunteer observers or co-operating agencies such as the Alberta Forest Service report daily information at monthly intervals. Climate data from about 680 stations (Map 1) were used in the preparation of this atlas. There are about 300 climate stations operating in Alberta.

The synoptic stations generally have long complete records of measurements including temperature, precipitation (amount and intensity), wind speed and direction, humidity and dew point temperature. The climate stations collect daily temperature and precipitation information. Since these stations are operated by volunteers, records tend to be of shorter duration than those of the synoptic stations; nevertheless, some volunteer climate stations have collected over 70 years of climate data.

Thermometers to measure maximum and minimum air temperature and sensors to determine relative humidity and dew point temperature are placed 1.2 metres above the ground in a louvered shelter called a Stevenson screen. The shelter protects the thermometers from direct sunlight and precipitation.

Precipitation is measured by catching it in calibrated rain and snow gauges. Rainfall intensity is measured by a tipping bucket rain gauge. The amount of snow on the ground is measured with a ruler.

The synoptic stations collect windspeed and direction at a height of 10 metres above the ground. These stations also measure atmospheric pressure, visibility, cloud cover and type, hours of bright sunshine, solar radiation and, in a few cases, evaporation.

Climate normals

A long period of weather observations is necessary to understand the expected climate. Like weather, climate also changes but very gradually. A 30-year-period is used to describe the present climate because it is long enough to filter out short-term fluctuations, but is not overridden by any long-term trend in the climate.

The term climate normal used in this atlas describes the average data for the latest 30 year period, which is 1951-80. The 30 year period is updated only every 10 years because of the massive amount of work involved, and the fact that the "normal" values would not change in a year. Normal is defined (Funk & Wagnall's Canadian College Dictionary, 1986) as "conforming to or consisting of a pattern, process or standard regarded as usual or typical; regular; natural". Normal climate is described by averages or means of climate parameters such as temperature, precipitation, wind and humidity. The averages allow quick and easy comparison of the climate of different areas, but they do a poor job of help-

ing understand the inherent variability of climate at any given location. It is important to remember that climate extremes are normal too; they are part of the **natural** variability of the cllimate.

Year to year variation provides temperature or precipitation values that are usually above or below the average. Variability is an expected feature of our climate, which must be remembered when looking at the average data presented in this atlas. The climate elements most often used in agriculture are precipitation, sunshine hours, temperature and information derived from temperature, such as degree-days and frost dates. Climate information is used as a long-term planning tool, either to select a location for a farm, or to plan a cropping program. The average is sometimes not adequate for planning because of extreme events which can be disastrous. For this reason, extremes for the entire period of record, that is as long as observations have been recorded at the site, are available.

Caution must be used when dealing with extremes because the period of record is very important. The shorter the period of record, the less reliable the extreme. If you want to know how much snow was dropped by the worst storm in a hundred years, you can't expect a station with only 20 years of records to provide it. The shorter the period of record, the more likely it is that a unique extreme event has been missed.

Map 8, presenting annual extreme minimum temperatures, and Map 9, presenting annual extreme maximum temperatures, are based on the entire preiod of observations available at each station. Map 8 presents the coldest temperatures ever recorded at that station. Map 9 presents the warmest temperature ever recorded at the station. The extreme values in Maps 8 and 9 are not averages, they are the actual coldest and warmest temperatures ever recorded during the period of observation.

The information presented in the Agroclimatic maps in this altas was obtained from the Canadian Climate Normals, 1951-80, published by the Canadian Climate Program, Atmospheric Environment Service, Environment Canada.

- Temperature and Precipitation (Volume 2),
- Precipitation (Volume 3),
- Degree days (Volume 4),
- Frost (Volume 6).

How to use climate information

Climate variability presents a great risk to agriculture. When a crop is planted, the questions are: Will it be too dry, too wet, too hot or too cold? Agriculture, however, is an industry where planning must consider the most likely conditions rather than the extremes because the key inputs and decisions are made well in advance of achieving results. The combined knowledge of climate and crop requirements should permit the selection of crop type and variety most suited to local conditions. Most crop varieties common to Alberta are bred to do well over a wide range of climate conditions. Also, severe weather will usually result in reduced yield and/or grade loss, not total crop failure. Crop insurance provides some financial protection from consequences of extreme events.

Farmers are risk managers, whose decisions today effect future outcomes. Climate variability is one of the risks that must be managed. In most cases, farmers have a number of choices of crops and varieties. They must judge crop suitability, fertilizer needs, yield and price potential, marketability as well as climate. For example, canola is represented by two crop types with significantly different growing season needs. Polish canola varieties require 80 - 85 days while Argentine varieties need 100 - 105 days. If a long growing season is available, the long season variety will be selected because of its greater yield potential. However, if seeding is delayed, a short season variety may be chosen because maturity can be achieved with less risk of frost damage. The length of the frost free period and the expected date of fall frost can provide a general guide for these decisions. The yield potential of some crops is closely related to the growing season length or heat units.

For each harvest of alfalfa at the 10 per cent bloom stage approximately 475 degree days above 5°C will be required. In an area like Lethbridge, receiving 1700 heat units, three cuts of irrigated alfalfa should be possible but in some years only two may be achieved. Each harvest has its own yield potential; hence, knowing that three cuts of alfalfa are possible then permits an estimate of the total harvest.

The averages of the climate elements provided in this atlas indicate "what has happened". This available history of our climate still remains our best guide as to the variety of climate conditions than can be expected over the next 5 to 10 years. Climate elements can also be expressed in terms of expected ranges or measures of variability. These define "what may happen" and "how often it will occur". The manager, combining knowl-

edge of the enterprise with that of "what should happen" and "what may happen" can then decide on the level of "risk" of adverse conditions that is acceptable.

Agricultural climate elements

The climate elements that most frequently influence agriculture are precipitation and temperature. These provide the energy for plant growth and the water required for the plant to take full advantage of the energy available. Animals are affected more by extremes of temperature and precipitation than by average conditions.

Precipitation

Precipitation provides the source of all terrestrial water. It occurs in many forms, rain, snow, dew and hail; but rainfall and snow are the greatest contributors. In Alberta precipitation is not uniformly distributed. Generally, in agricultural areas, 50 - 60 per cent of annual precipitation occurs during the growing season, mostly as rain. Figure 3 shows the long term average distribution of precipitation for Medicine Hat, Edmonton and Grande Prairie for each month. Precipitation in southern Alberta peaks in June while in central Alberta and the Peace regions the peak occurs in July. The June peak in precipitation in southern Alberta accounts for the fact winter wheat normally outyields spring wheat.

Precipitation in any month is extremely variable with dry spells of a month or longer possible at any time. The duration of dry spells tends to be shorter in central Alberta and the southern Peace Regions than elsewhere. Figure 4 shows the variability of precipitation for the crop year (Sept 1 - Aug 31) and for the May 1 - July 31 period for 1950 to 1988, for Lethbridge, Edmonton and Beaverlodge. The maximum, mean and minimum recorded over the entire period of record are also shown. In general the variability of precipitation is greater in southern Alberta and the Peace River area than in central Alberta. During the growing season, precipitation variation at Lethbridge and Beaverlodge is about 50 per cent of the mean while only about 30 per cent at Edmonton.

Because crop water use generally exceeds precipitation during the growing season, precipitation between the growing seasons is significant to crop growth and production. Soil moisture reserves are built up from this precipitation either in an eight-month period between harvest and seeding as in an annual cropping system or in a 20-month period as in a crop fallow rotation. In

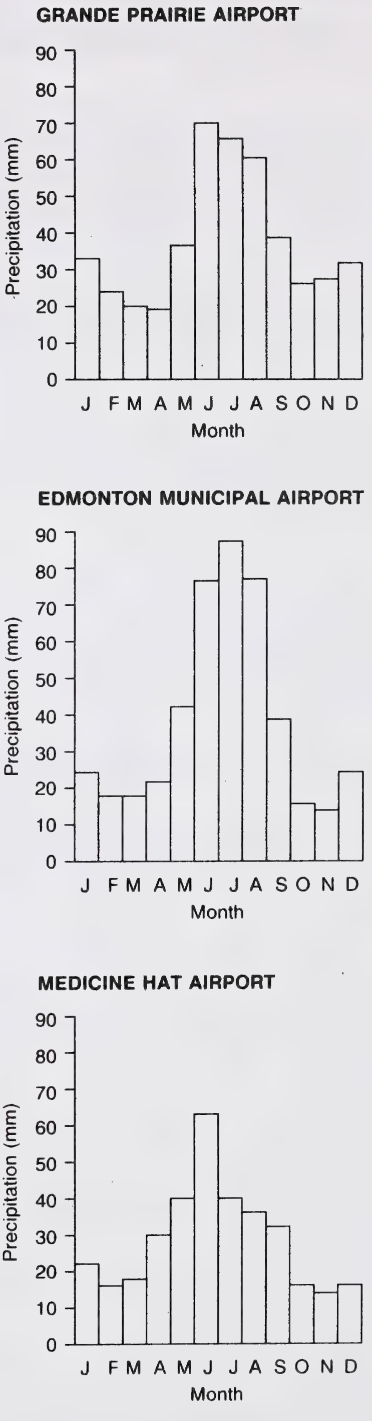

Figure 3. Average monthly precipitation 1951-80

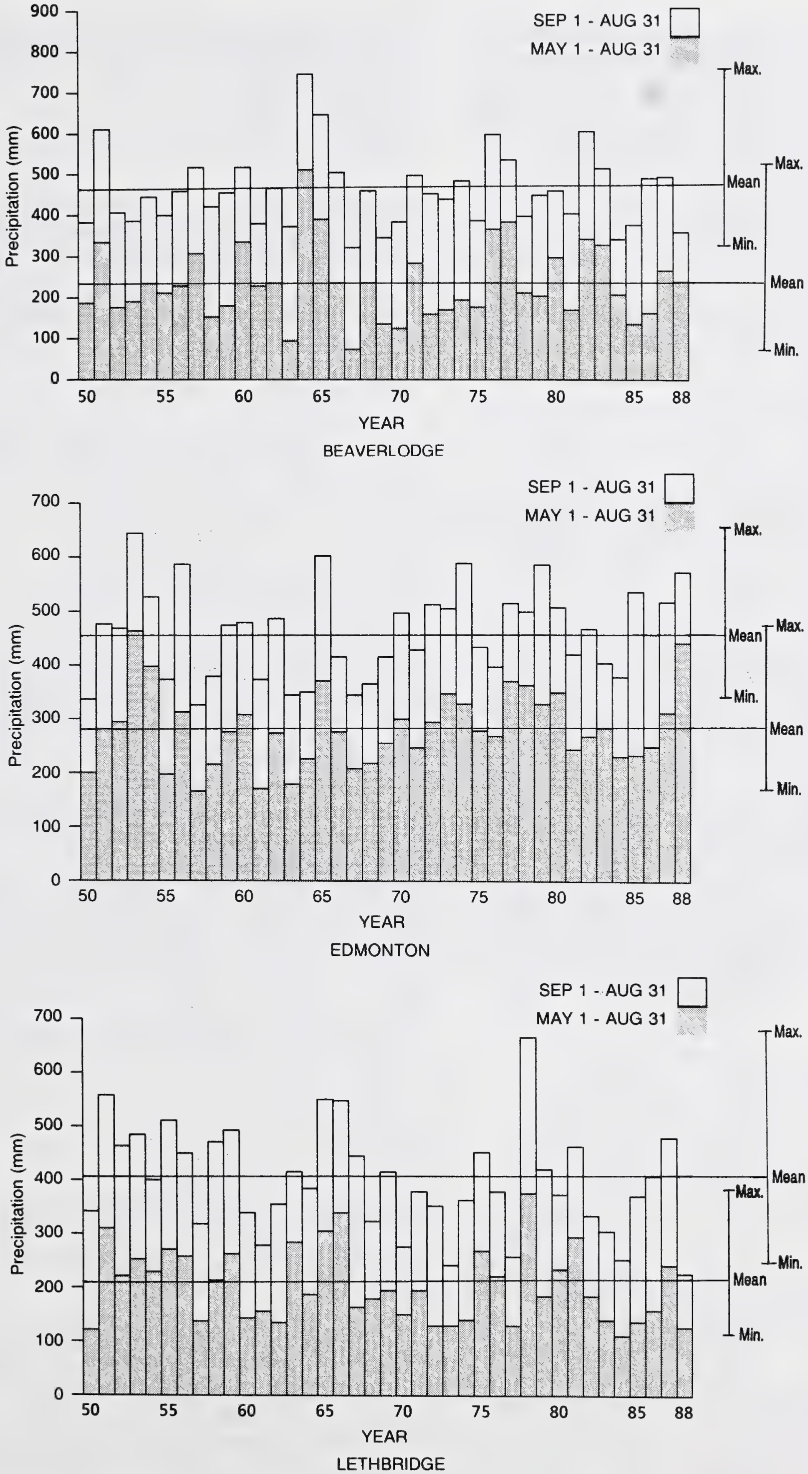

Figure 4. Annual and growing season precipitation 1950 - 1988

the eight-month storage interval between annual crops, 25 to 30 per cent of the precipitation will be rain, the rest will be snow. The storage efficiency of non-growing season precipitation in the Brown and Dark Brown Soil Zone will be 40 to 45 per cent on stubble fields cultivated once. In other soil zones, storage efficiency may be less.

Temperature

Temperature affects all living things. Each plant and animal has its own specific optimum temperature for growth and a temperature range over which it thrives. Once temperatures outside this range are encountered, the animal or plant suffers and growth slows. Cool season crops such as wheat, barley and oats don't grow well at temperatures below 5˚C, they grow best at temperatures of 25 - 30˚C and are stressed by temperatures above 30˚C. Warm season crops such as corn have temperature needs that are 5 to 10 ˚C warmer.

In the winter, temperature decreases at higher latitude and with distance from the mountains and the decreasing effectiveness of the Chinook in modifying the climate. In the summer, the temperature pattern is different. The highest elevations have the lowest temperatures, but the latitude effect is reduced. The highest temperatures occur where the elevation and precipitation are the least. Upland areas will have lower temperatures than the surrounding lowland area because temperatures drop 1˚C for each 100 metres rise in elevation. Also, areas with sandy soils such as Fort Vermilion, tend to have a somewhat higher air temperature than surrounding areas with heavier, wetter soils.

Heat units

Temperature affects the rate of plant growth. The concept of growing degree-days, also called heat units, assumes that plant growth is related directly to temperature if there are no other limitations. This is generally true as long as temperatures are not high enough to cause damage to plants. There is a minimum temperature at which growth starts, which is 5˚C for most of the major crops growing in Alberta. The minumum threshold temperature is 10˚C for crops like beans and corn. The upper thermal threshold for most crops found in Alberta is 30˚C.

To calculate the degree-days for any particular day, the average daily temperature is determined from the maximum and minimum temperature. The base temperature is subtracted from the average temperature.

maximum temperature	27˚C
minimum temperature	15˚C
average temperature (27+15) ÷ 2 =	21˚C
Degree-days above 5˚C = 21 - 5 =	16
Degree-days above 10˚C = 21 - 10 =	11

If the average daily temperature is below the base temperature, the degree-day value equals zero. Negative values are not calculated because the crop is not set back. It is important, when applying degree-days, to know the temperature scale and base temperature used for the calculation.

Degree-day normals are prepared by accumulating the degree days from each day of each month in the growing season for a thirty year period. From these values, the average number of monthly or seasonal degree-days are calculated by computing the average.

Degree-day normals permit comparison of areas for their similarities or differences in growing potential. Crop requirements for heat may be matched to the number of degree-days available. For example, the two types of canola available for seeding have quite different heat unit requirements. Argentine varieties require 1040 to 1100 heat units, Polish varieties only require 860 to 920. Looking at the number of degree-days available for growth will help in selecting the type most suited to an area. In cases of delayed seeding or reseeding, heat units expected in the remaining part of the growing period will help determine which type to seed. Alfalfa will produce a cutting with 475 degree-days if harvested at 10 per cent bloom. It is possible to estimate the next harvest time from the current degree-day accumulation and the weather expected.

There is a different set of heat units called corn heat units for measuring growth potential. These are calculated using separately the maximum and minimum temperatures. For further information, the publication Corn units for Corn in southern Ontario is available from the Ontario Ministry of Agriculture and Food. Corn varieties are all rated by the number of degree-days required to mature. Comparing the corn heat units available in an area to that needed by each variety permits the choice of a variety suited to the area.

Another use of the degree-day concept is heating degree-days, which indicate the amount of heating required for buildings. Heating degree-days are calculated by subtracting the daily average temperature from the base temperature of 18˚C. From these values the energy needed to maintain a comfortable temperature in a building can be estimated. Heating degree-

days or some other similar unit with a different base temperature could be used to estimate livestock feed requirements

Frost free period

Temperature is measured at 1.2 metres above the ground surface at weather stations by thermometers located in louvered screens. A few stations, such as those at Agriculture Canada Research Stations, also record temperatures 3 or 4 cm above a short grass surface using thermometers exposed to the sky, which are more representative of the crop temperature. In late spring and early fall when frost occurs it has been shown that the grass minimum temperatures are always lower than that found at the screen height. The difference varies but is generally from 2 to 5°C.

When using screen temperature information for estimating frost dates, it must be remembered that the crop will be cooler than the screen data indicates. The important consideration is the relative comparison between areas that the data provides. Within any given area, local conditions may cause a variation in the timing of the last frost by as much as several weeks.

TABLE 1. Frost Dates For Five Alberta Locations

Spring

	Latest Last Spring Frost	1 in 10 years	1 in 4 years	Probability of 0°C or lower on or after indicated date 1 in 3 years	1 in 2 years	2 in 3 years	3 in 4 years	9 in 10 years	Earliest Last Spring Frost
Lethbridge CDA	July 3	June 11	May 26	May 25	May 21	May 18	May 13	May 12	May 8
Calgary A	July 11	June 10	May 31	May 29	May 25	May 19	May 17	May 11	May 4
Edmonton Namao	June 12	May 29	May 21	May 17	May 13	May 7	May 4	Apr 26	Apr 11
Grande Prairie	June 17	June 5	May 28	May 22	May 16	May 13	May 11	May 6	May 3
Fort Vermilion	July 5	June 18	June 11	June 8	May 31	May 27	May 23	May 7	May 1

Fall

Location	Earliest First Fall Frost	1 in 10 years	1 in 4 years	Probability of 0°C or lower on or after indicated date 1 in 3 years	1 in 2 years	2 in 3 years	3 in 4 years	9 in 10 years	Latest First Fall Frost
Lethbridge CDA	Aug 25	Sept 3	Sept 8	Sept 10	Sept 15	Sept 26	Sept 29	Oct 6	Oct 6
Calgary A	Aug 16	Aug 27	Sept 5	Sept 8	Sept 12	Sept 18	Sept 20	Oct 2	Oct 19
Edmonton Namao	Sept 3	Sept 4	Sept 10	Sept 12	Sept 18	Sept 25	Oct 2	Oct 6	Oct 8
Grande Prairie	Aug 15	Aug 19	Sept 2	Sept 5	Sept 8	Sept 17	Sept 19	Sept 29	Oct 7
Fort Vermilion	July 17	Aug 5	Aug 16	Aug 21	Aug 31	Sept 4	Sept 6	Sept 18	Oct 2

TABLE 2 . Length of Frost Free Period in Days for Five Alberta Locations.

Spring

	Shortest Frost Free Period	1 in 10 years	Probability of frost free periods being equal or less than given number of days 1 in 4 years	1 in 3 years	1 in 2 years	2 in 3 years	3 in 4 years	9 in 10 years	Longest Frost Free Period
Lethbridge CDA	85	105	111	112	121	127	134	143	164
Calgary A	52	84	101	104	110	115	118	134	154
Edmonton Namao	83	108	117	121	129	135	139	146	162
Grande Prairie	75	87	98	106	114	120	124	140	144
Fort Vermilion	34	46	75	79	87	98	103	117	124

The actual frost date (0˚C) varies each year. The variation of frost dates for Lethbridge, Calgary, Edmonton, Grande Prairie and Fort Vermilion are shown in Table 1 for spring and fall.

It can be seen that about 50 per cent of the last frosts occur in the spring in a period of a week before and after the average frost date. In the fall the first frost will occur 50 per cent of the time in a period of one week before and about one and a half weeks after the average frost date.

The frost free period is the number of days between the average last date of 0˚C in the spring and the average first date of 0˚C in the fall. This provides a measure of the period that plant growth should occur uninterrupted by frost; hence a method of comparing growing conditions within the province. Table 2 illustrates the variation of length of frost free periods in days at Lethbridge, Calgary, Edmonton, Grande Prairie and Fort Vermillion.

The effect of a 100-day frost free period is not equal across the province because day length varies. The longer day length in the Peace River area, compared to southern Alberta, appears to offset the shorter frost free period found in the north. Each crop reacts differently to increasing day length, so no general adjustment of frost free periods for day length is possible.

Most of the field crops produced in Alberta can withstand temperatures as low as -2˚C without significant damage. Many seedlings can withstand temperatures of -4 to -6˚C without harm. This permits spring seeding to start when soil temperatures reach a suitable level and not to wait until the last chance of frost disappears. The crop stage most susceptible to frost damage is flowering.

Growing season length

The growing season is the period of time each year during which perennial crops such as pastures and forages can grow. The growing season is longer than the frost free period. Plant growth begins whenever air and soil temperature are above freezing most of the time. When the average daily air temperatures reach 5˚C for a 5-day period, daily heat unit accumulations begin. The start, end and length of the growing season will be different every year. The variability in the average start, end, and length of the growing season will be similar to that illustrated in Tables 1 and 2 for the frost free period. This information can be used to compare the growing season length across the province. As with frost free period and degree-day calculations, the length of growing season does not account for the effect of longer day length in northern Alberta compared to southern Alberta. Small areas of above average conditions will be found around Edmonton and in the vicinity of Taber and Bow Island. Other smaller pockets of longer growing season will also exist because of local conditions.

Discussion of agroclimatic maps

Map 2: Annual total precipitation

Annual total precipitation includes both snow and rain. The long term average annual precipitation in Alberta varies from a low of about 300 mm to more than 600 mm in the mountains. Annual precipitation is greatest in the mountains and decreases as elevation decreases. The effect of elevation has been estimated as 35 mm for each 100 metres of elevation change. The effect of elevation change on precipitation can be seen when one visits areas such as the Cypress Hills, the Hand Hills, Swan Hills or Saddle Hills.

Map 3: Annual total snowfall

Snowfall accounts for 30 to 40 per cent of annual precipitation in Alberta. The pattern of snowfall is similar to that of total precipitation, with the mountains receiving the most and the prairies the least. The amount of snow remaining on the ground will be much less in the area affected by Chinook winds. The area southwest of Highway 1 frequently lacks a permanent winter snow cover. The likelihood of having intermittent snow cover increases with the number of Chinook days (Figure 1).

Map 4: May 1 to August 31 total precipitation

Precipitation from May 1 to August 31 provides most of the moisture for plant growth. It varies from slightly below 200 mm in the driest prairie areas up to 350 mm in the mountains. About 60 per cent of the variation in crop yield can be explained by the variation in May 1 to August 31 precipitation. This is particularly true for annual crops since they are seeded in early May and harvested in late August or early September.

Map 5: September 1 to April 30 total precipitation

Precipitation in this period ranges from less than 150 mm in the driest prairie region to more than 250 mm in the mountains. This precipitation is a mixture of rain and snow. Most agricultural areas will receive about 50 mm of rain with the balance as snow. This precipitation is the source of the soil moisture reserves that are built up between growing seasons.

Map 6: January daily mean temperature

Average January temperature varies from -9°C in the southwest to -24°C in the north. Warm Chinook winds influence the temperature pattern with warmer temperatures extending north along the eastern slopes of the mountains from southern Alberta.

Map 7: July daily mean temperature

Average temperatures in July range from 19°C in the southeast to 13°C in the mountains. In July, the dry areas with little cloud cover are subject to greater solar heating. This is seen in the southeast corner of the province, which experiences the warmest average July temperatures. Areas of high elevation tend to be cooler. These two factors contribute to an east-west temperature gradient in the southern half of Alberta.

Map 8: Annual extreme minimum temperature

The coldest temperatures recorded in Alberta range from -42°C in the south to -50°C in the northern one-third of the province. This map is based on the entire temperature record available at each station. The effect of latitude is modified to some extent along the mountains by the Chinook. Winter wheat production in Alberta is concentrated in or near the region delineated by the -42°C line.

Map 9: Annual extreme maximum temperature

The hottest temperatures ever recorded in Alberta vary from 42°C north of Medicine Hat to 30°C or less in the mountains. This map is based on the entire temperature record available at each station. Lower elevation and dryer soils contribute to higher temperatures. The highest extreme maximum temperatures occur in southeastern Alberta, where temperatures can get hot enough to cause plants to suffer from heat stress.

Map 10: Annual total degree-days above 5°C

The growing degree-days above 5°C varies from a high of 1900 in Medicine Hat to less than 1200 outside of the major agricultural areas.

Map 11: Annual total degree-days below 18°C

Annual total degree-days below 18°C varies from less than 5000 in southern Alberta to more than 7000 in the northern part of the province. Annual total degree-days below 18°C increase with both latitude and elevation in Alberta.

Map 12: Frost free period (days above 0°C)

Frost free periods in Alberta vary from more than 115 days to less than 85 days in non-agricultural areas. The frost free period is about a month longer in southern Alberta compared to the rest of the province. Areas of higher elevation have the shortest frost free period.

Map 13: Date of last spring frost (0°C)

The last spring frost dates vary from before May 21 to after July 1. Most agricultural areas of Alberta are frost free after May 31. The southeast is frost free earliest and the north is frost free only a few days to weeks later. Frost can occur in the mountain regions any time in the summer.

Map 14: Date of first fall frost (0°C)

The average first fall frost can be as late as September 21 in southern Alberta or as early as September 1 in the northern agricultural zones. In non-agricultural areas in the north and the mountains frost before September 1 is common.

Map 15: Date of start of growing season (5°C)

Growth of perennial crops will start in southern Alberta before April 21 and by May 1 in the agricultural areas of northern Alberta. Outside of the agricultural areas in northern Alberta and in the mountain areas, start of the growing season may be delayed beyond May 1.

Map 16: Date of end of growing season (5°C)

The end of plant growth will be later than October 20 in southern Alberta and as early as September 20 in the northern agricultural area. In parts of the mountains and in extreme northern areas the growing season may end earlier.

Map17: Length of growing season (days above 5°C)

The growing season, based on 5°C average daily temperature, will vary from more than 185 days in southern Alberta to less than 160 days in northern Alberta and the mountain areas.

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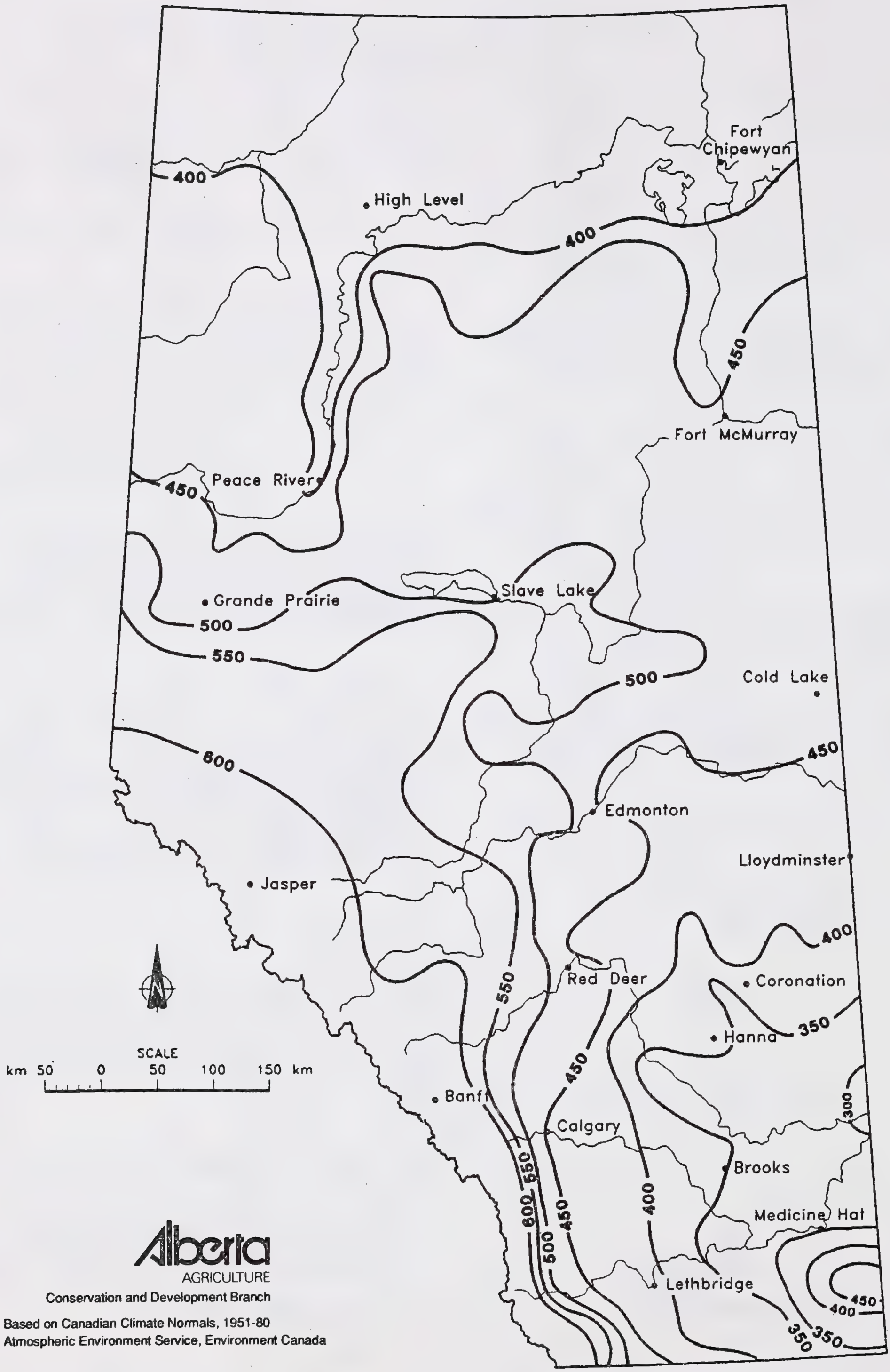
Map 1. Location of stations recording climate data



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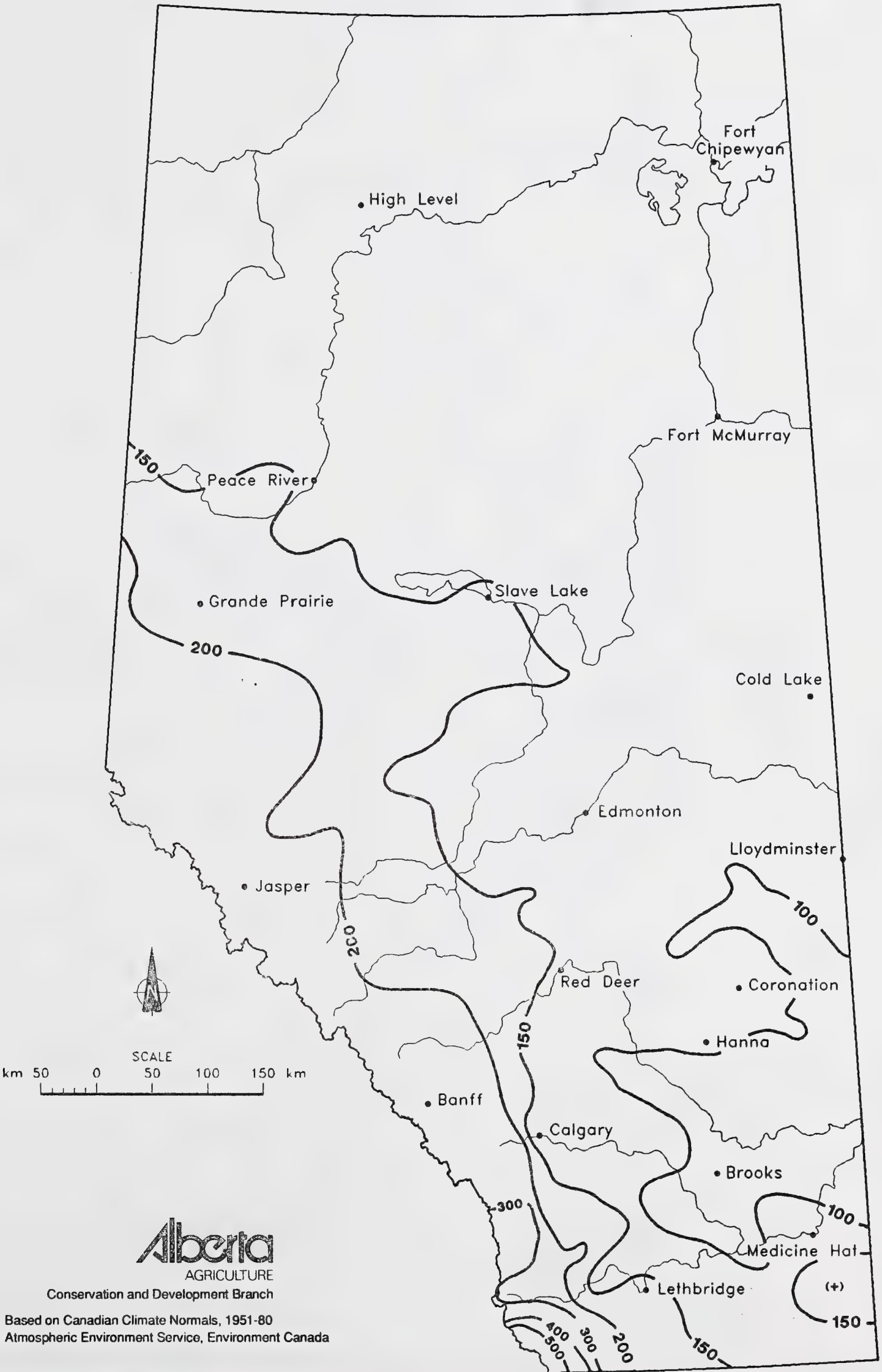
Based on Canadian Climate Normals, 1951-80
Atmospheric Environment Service, Environment Canada

Map 2. Annual total precipitation (mm) 1951- 80



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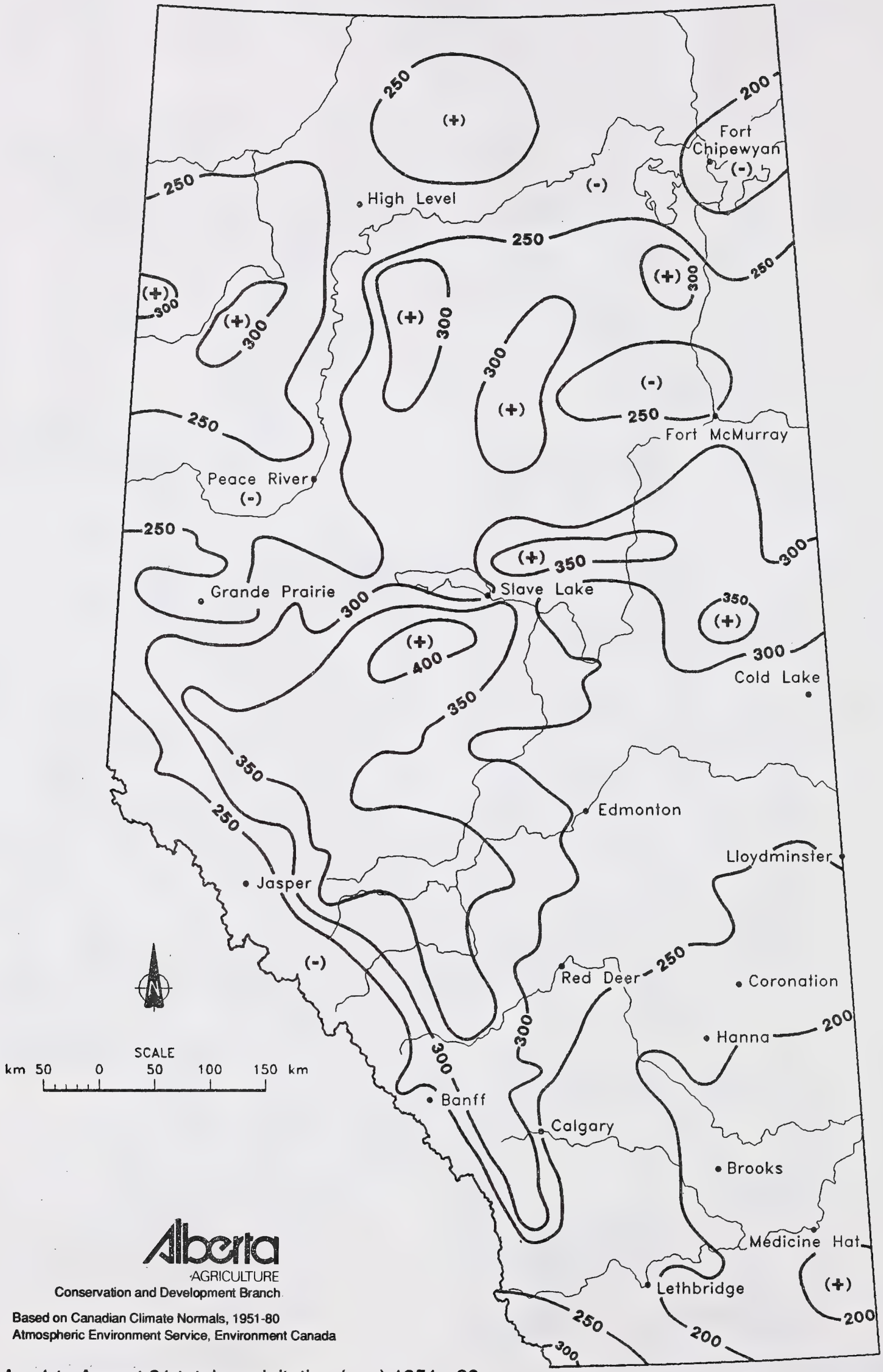
Map 3. Annual total snowfall (cm) 1951 - 80



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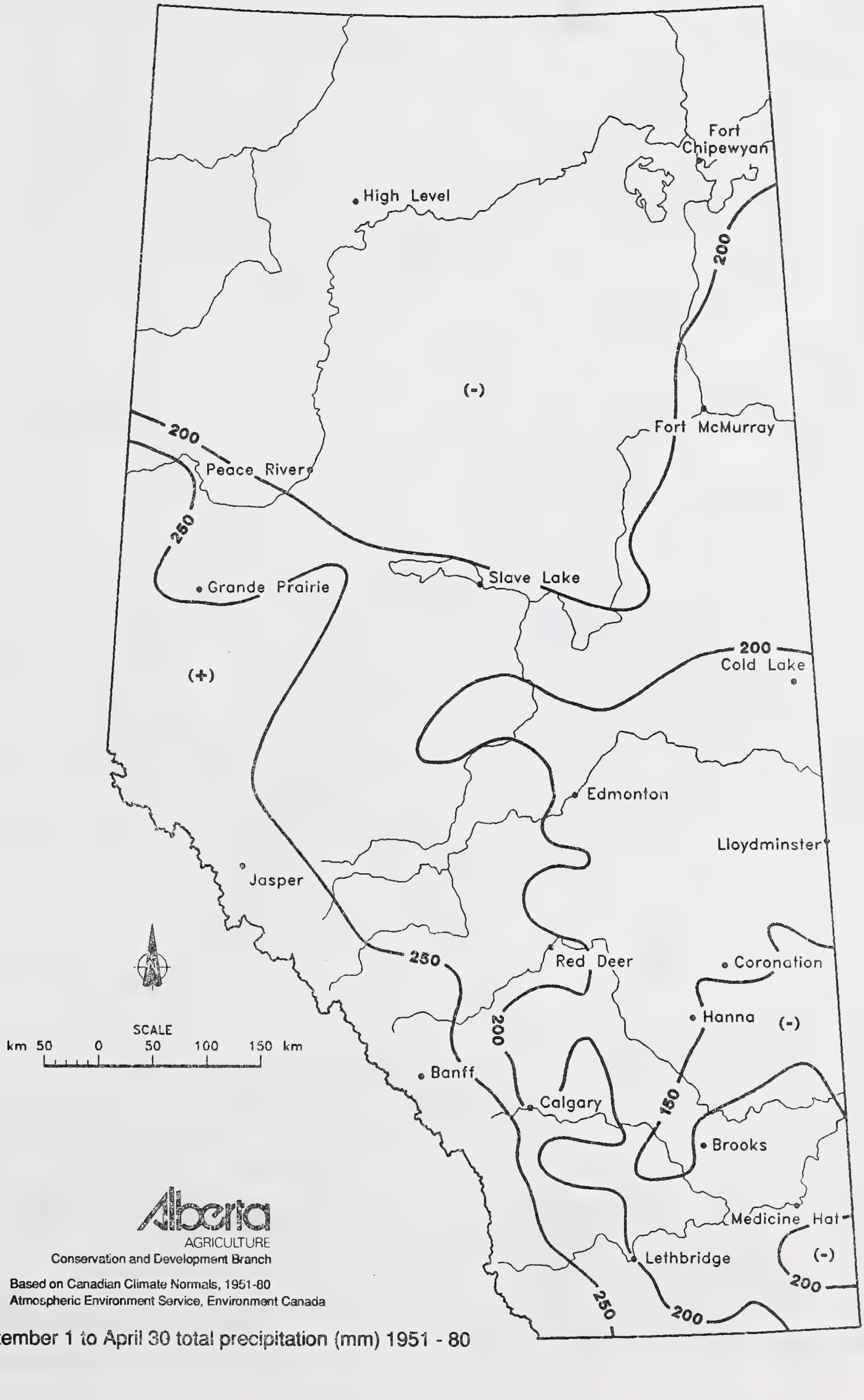
Map 4. May 1 to August 31 total precipitation (mm) 1951 - 80



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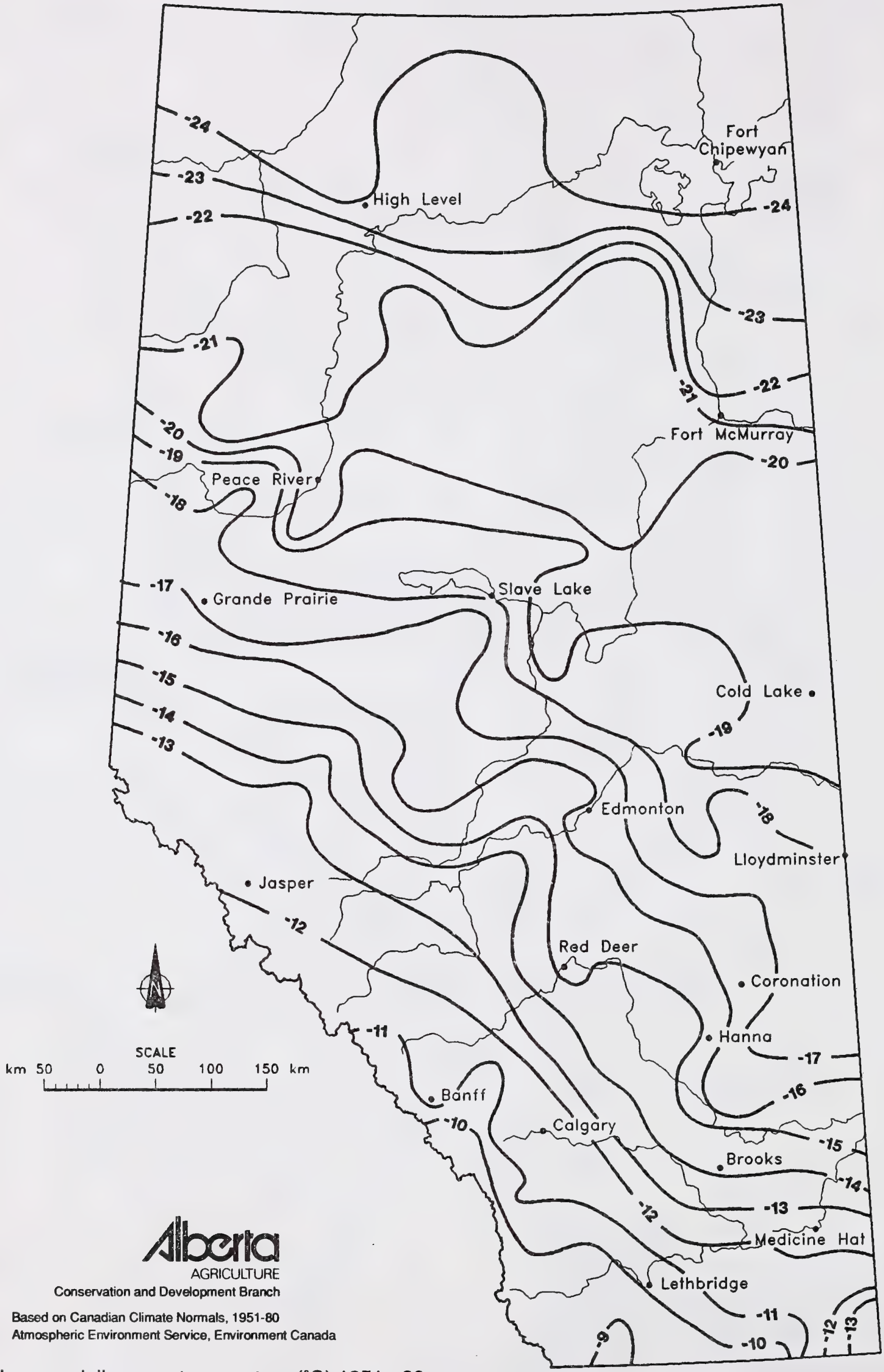
Map 5. September 1 to April 30 total precipitation (mm) 1951 - 80



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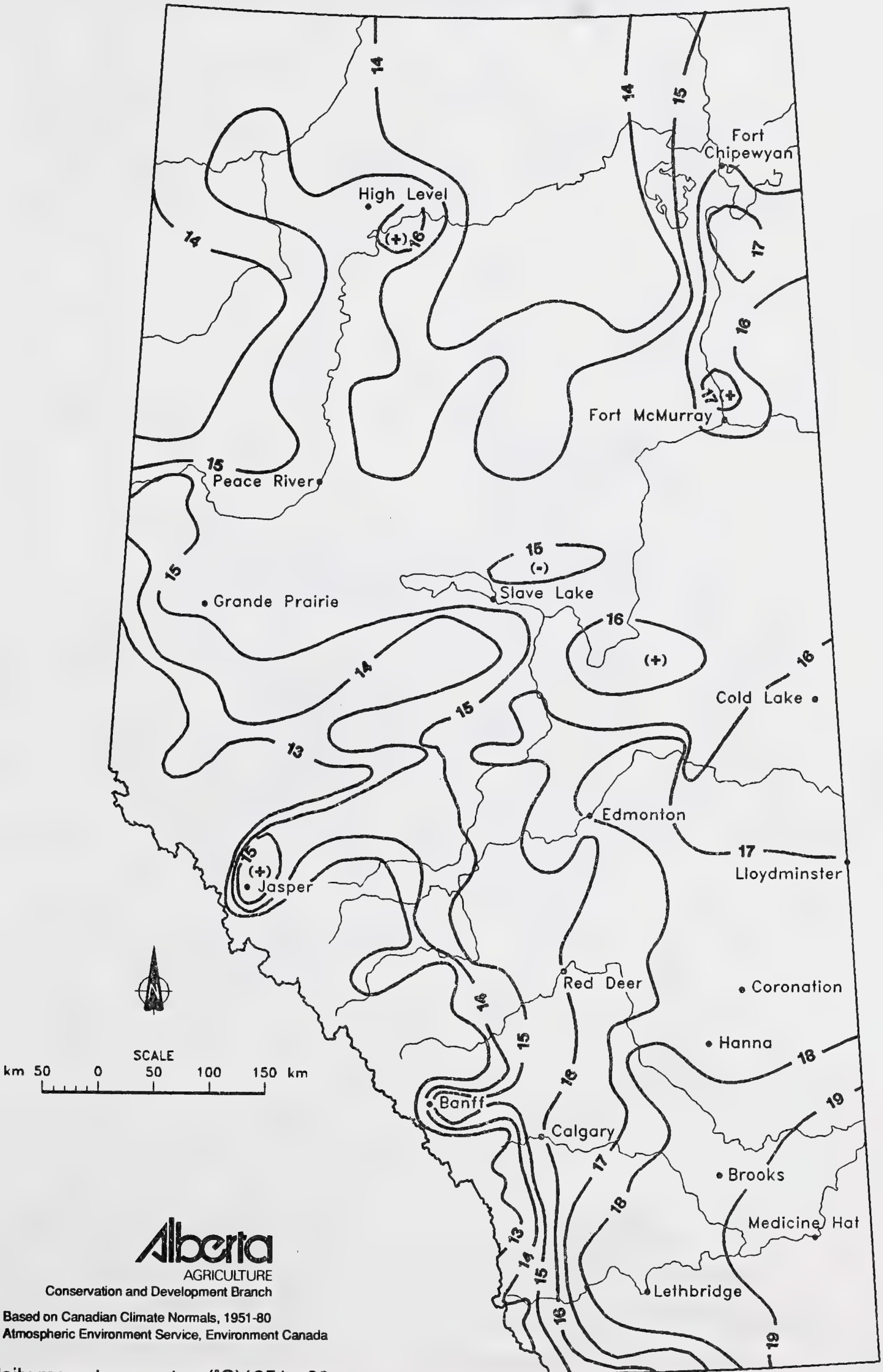
Map 6. January daily mean temperature (°C) 1951 - 80



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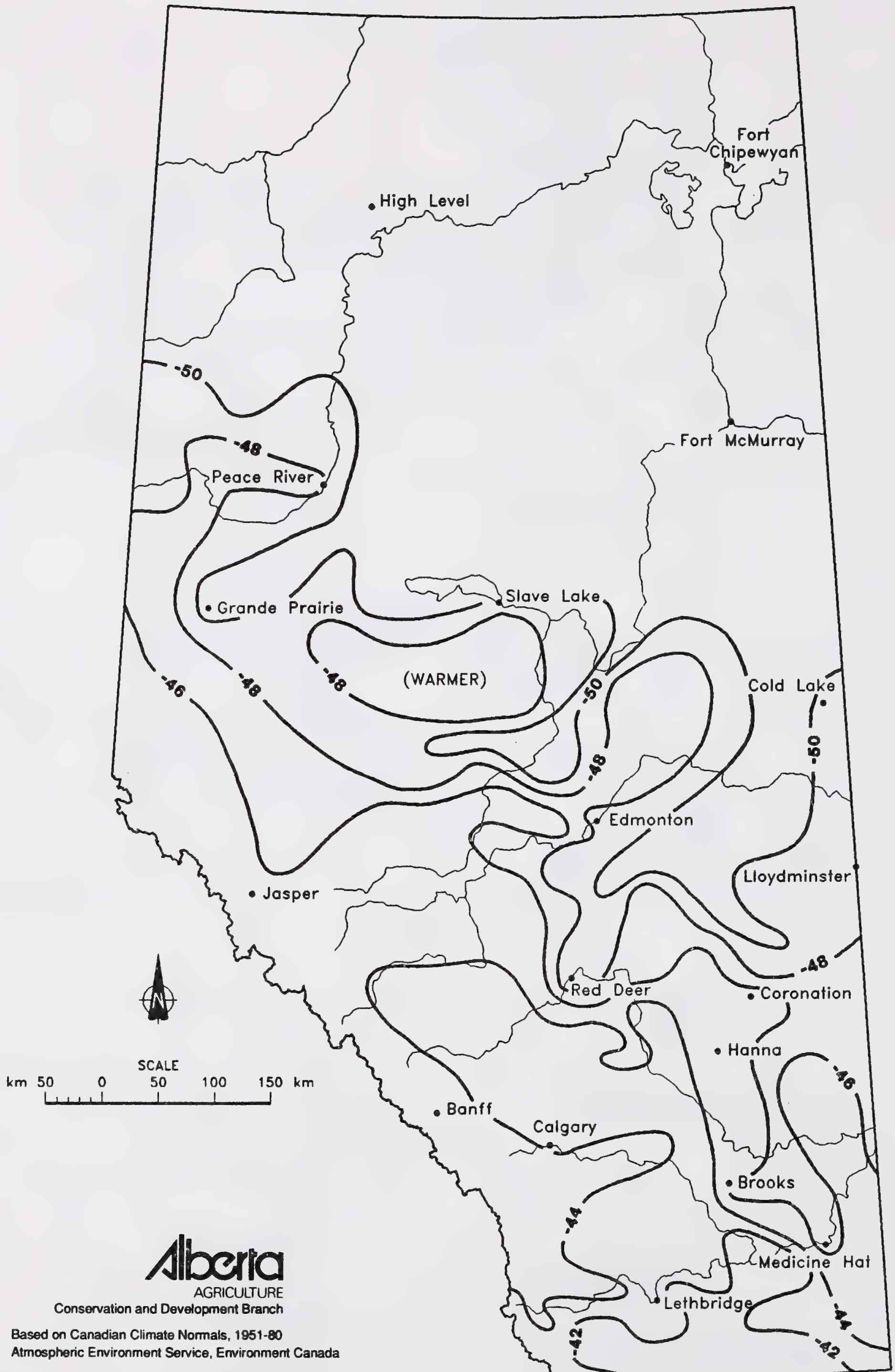
Map 7. July daily mean temperature(°C)1951 - 80



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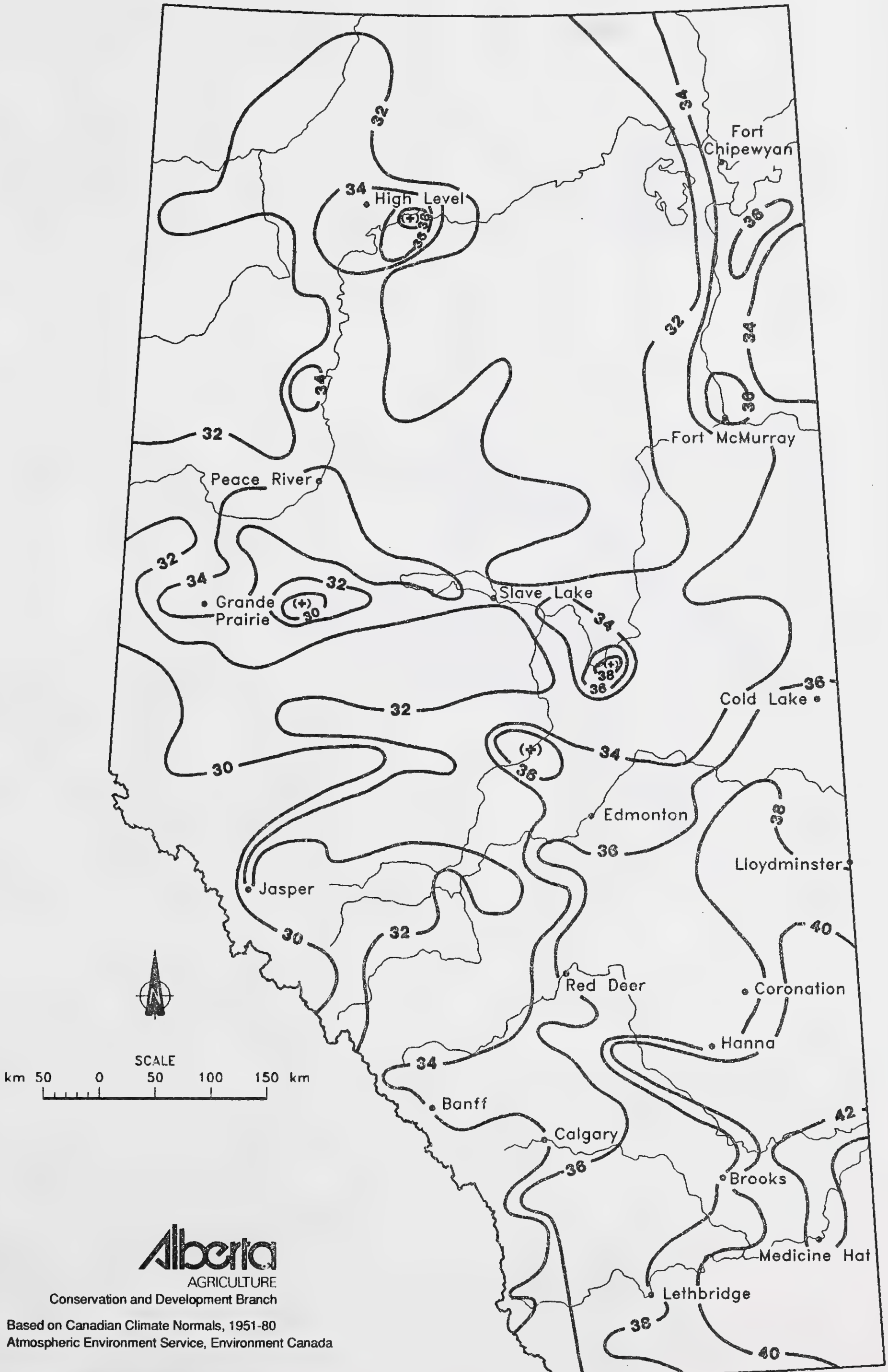
Map 8. Annual extreme minimum temperature (°C)



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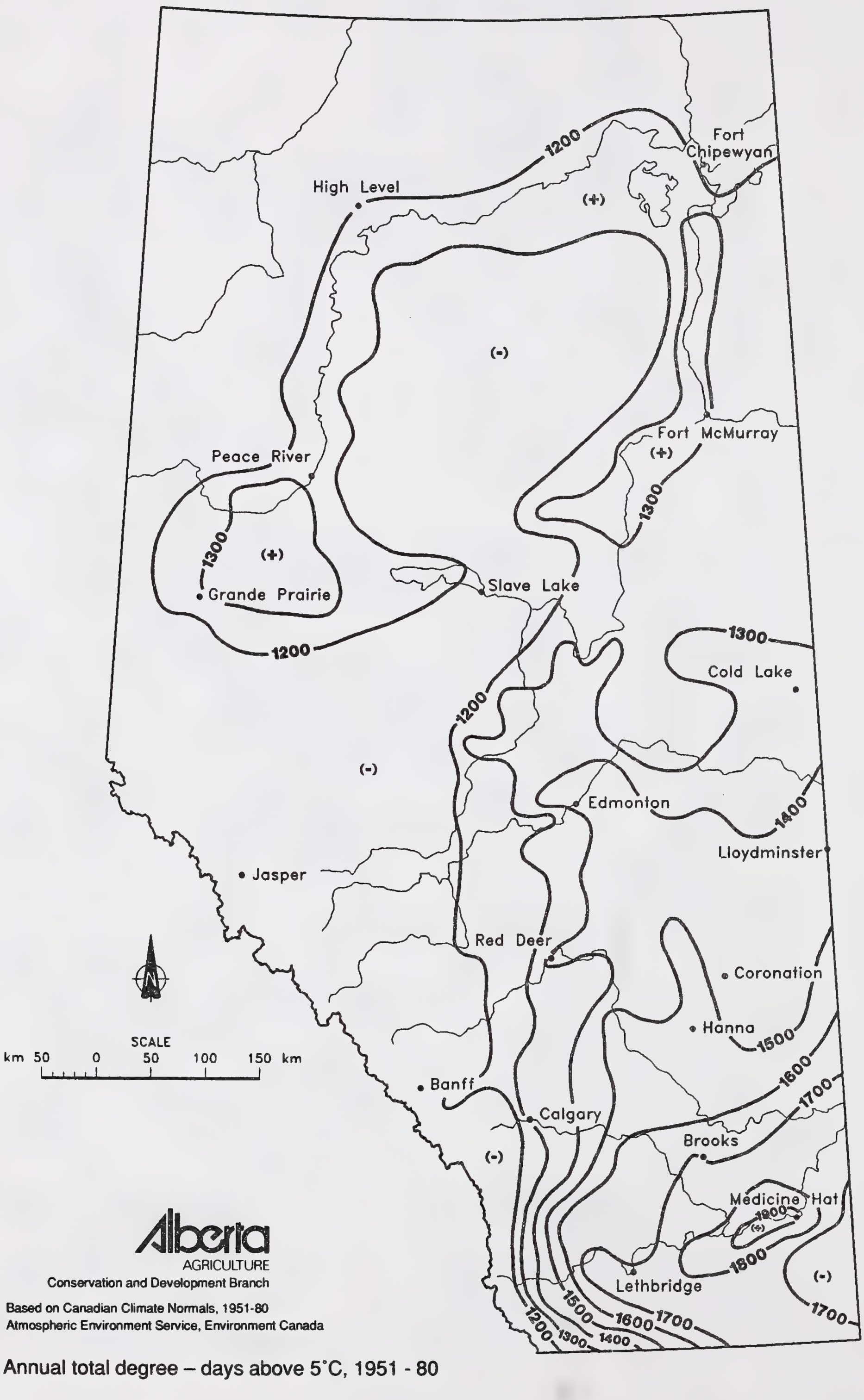
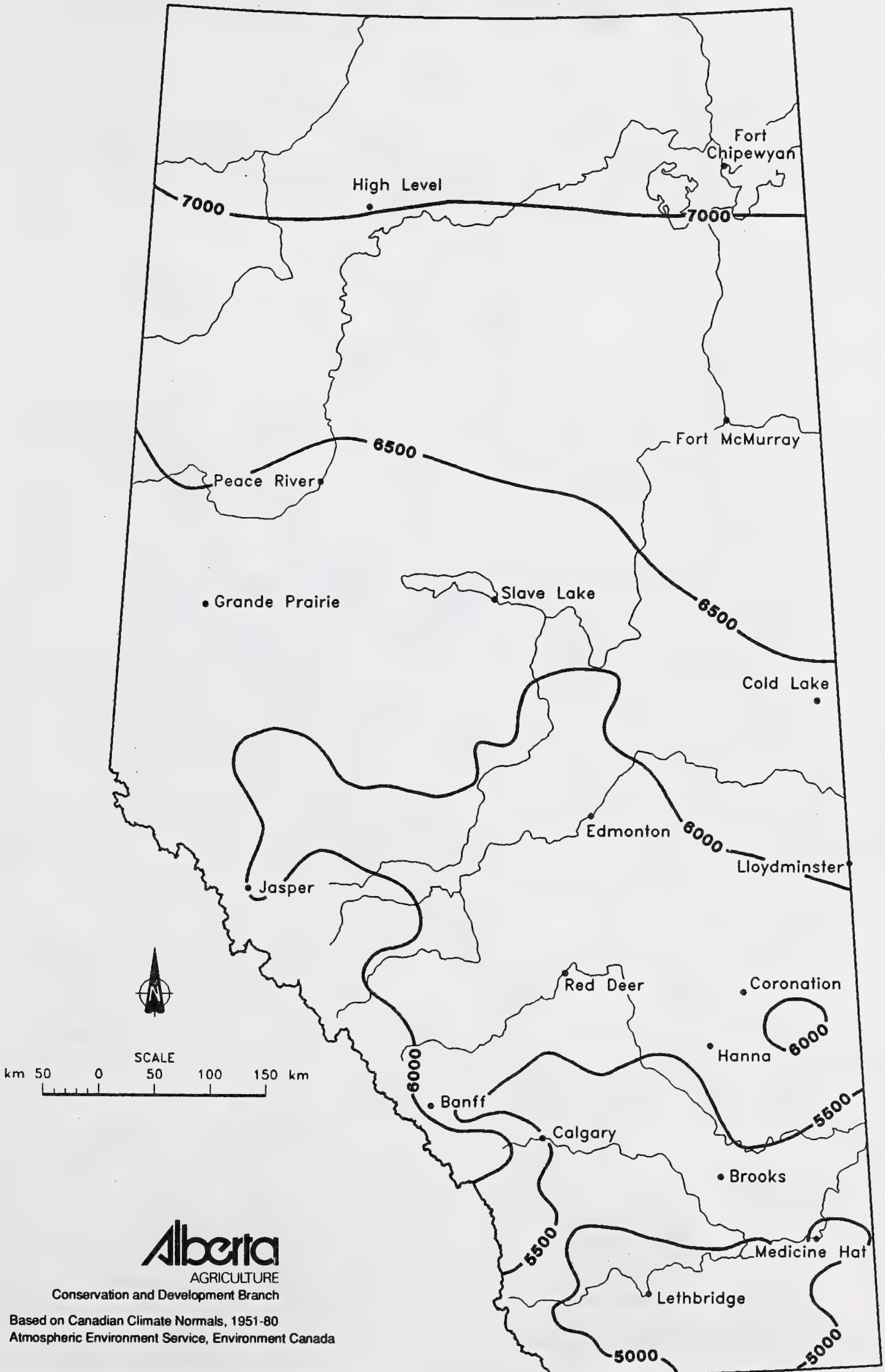
Map 9. Annual extreme maximum temperature (°C)



Map 10. Annual total degree – days above 5°C, 1951 - 80



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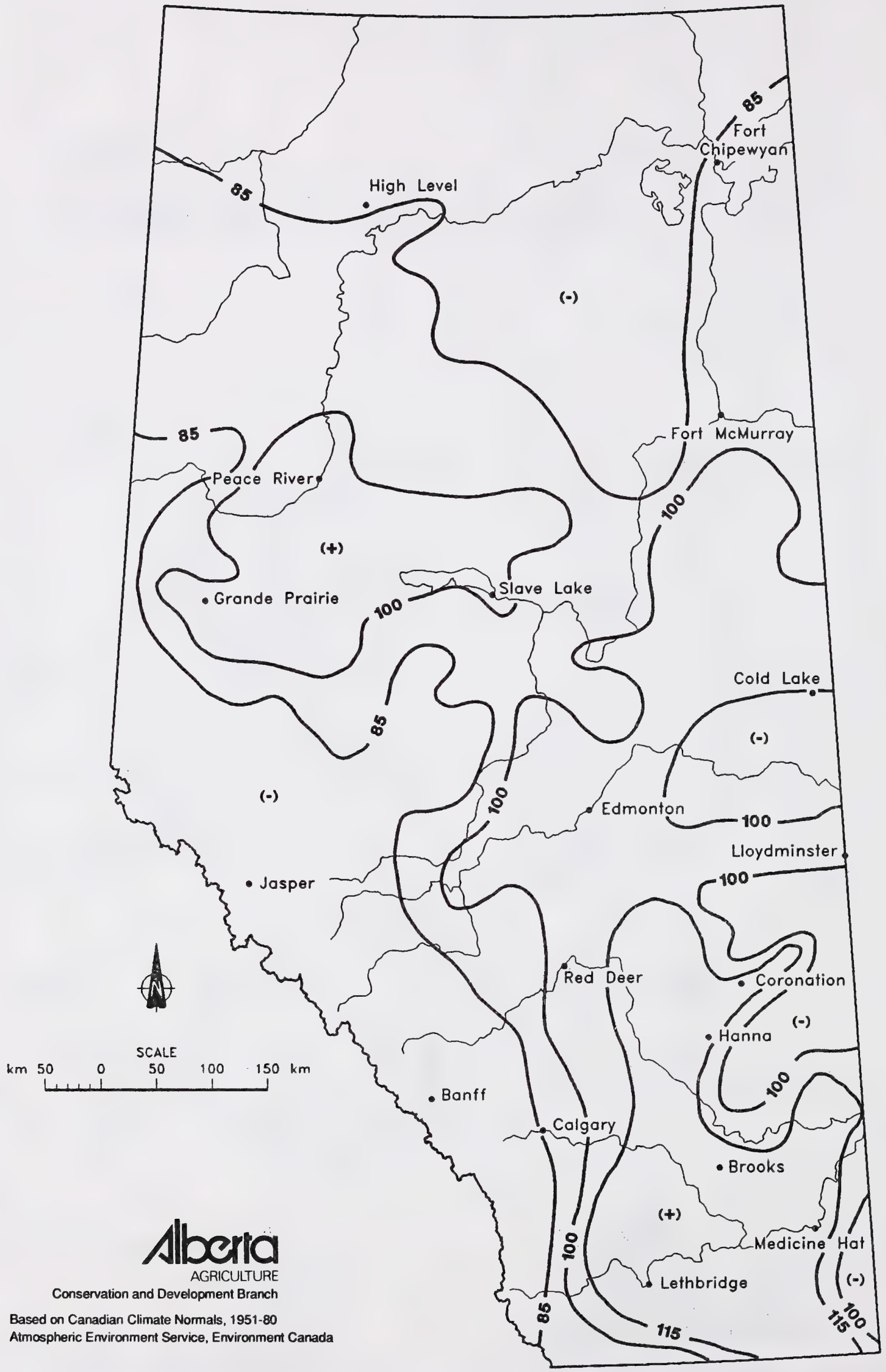
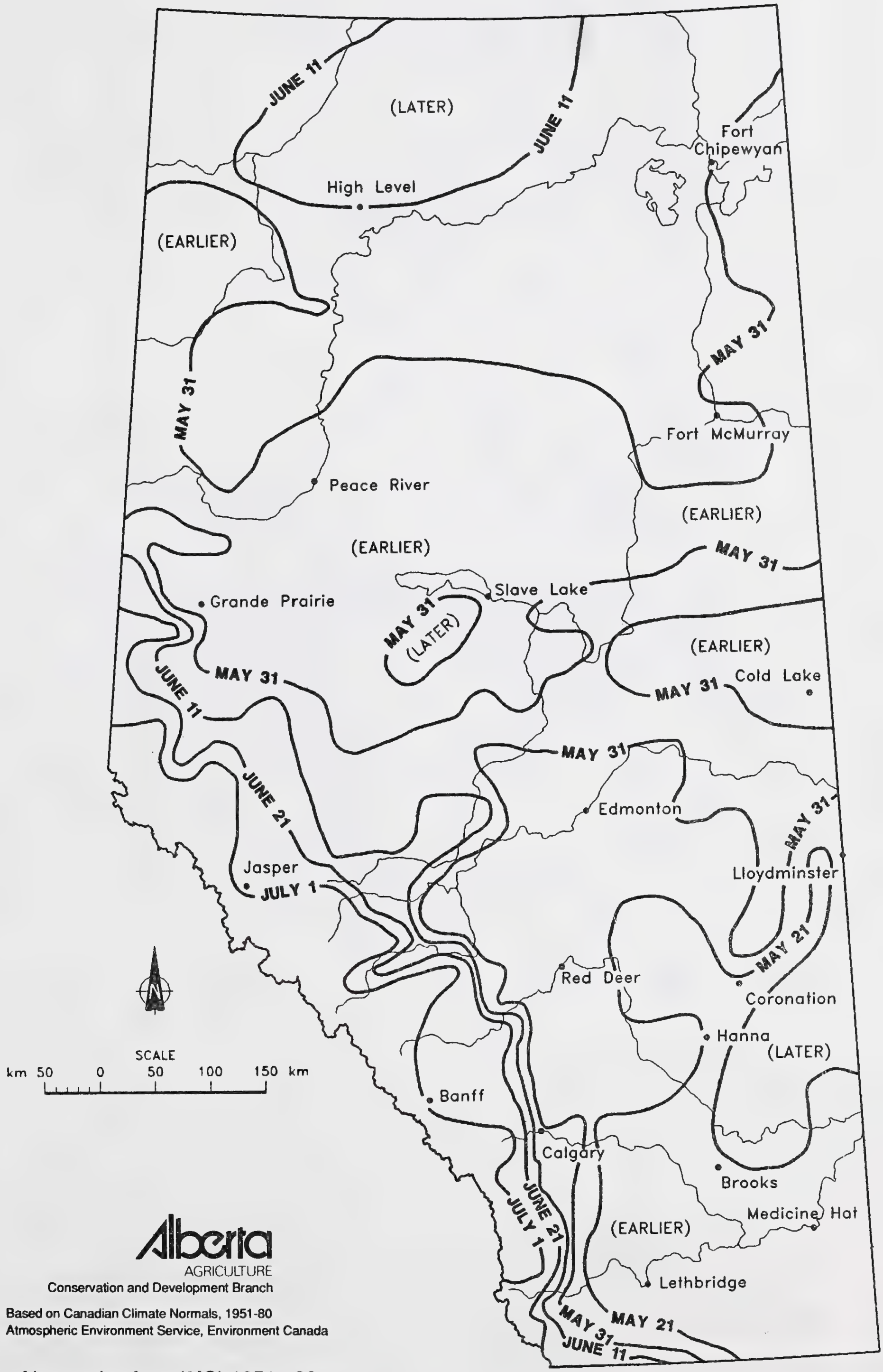
Map 11. Annual total degree – days below 18°C, 1951 - 80



Map 12. Frost-free period (days above 0° C) 1951 - 80



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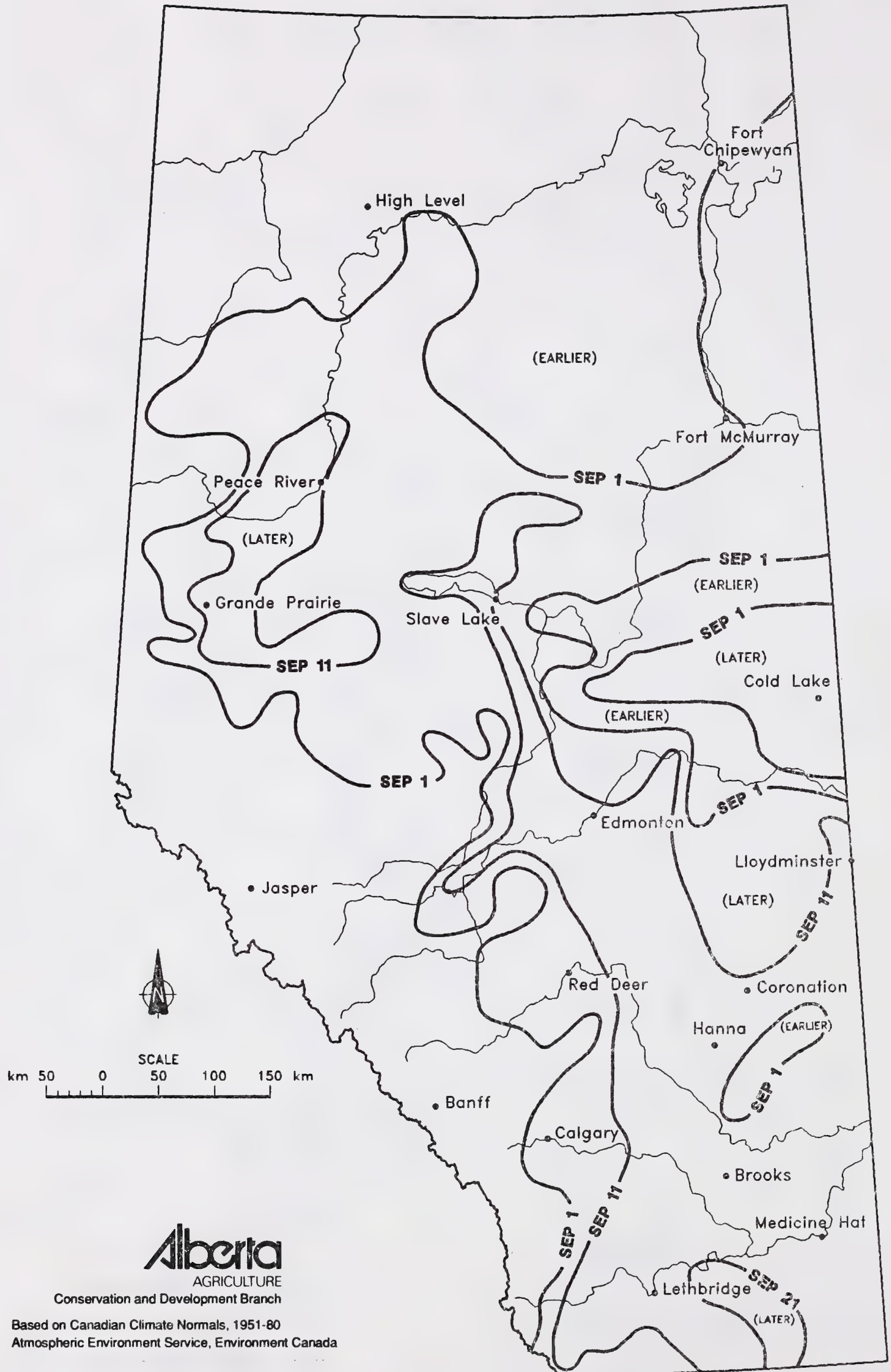
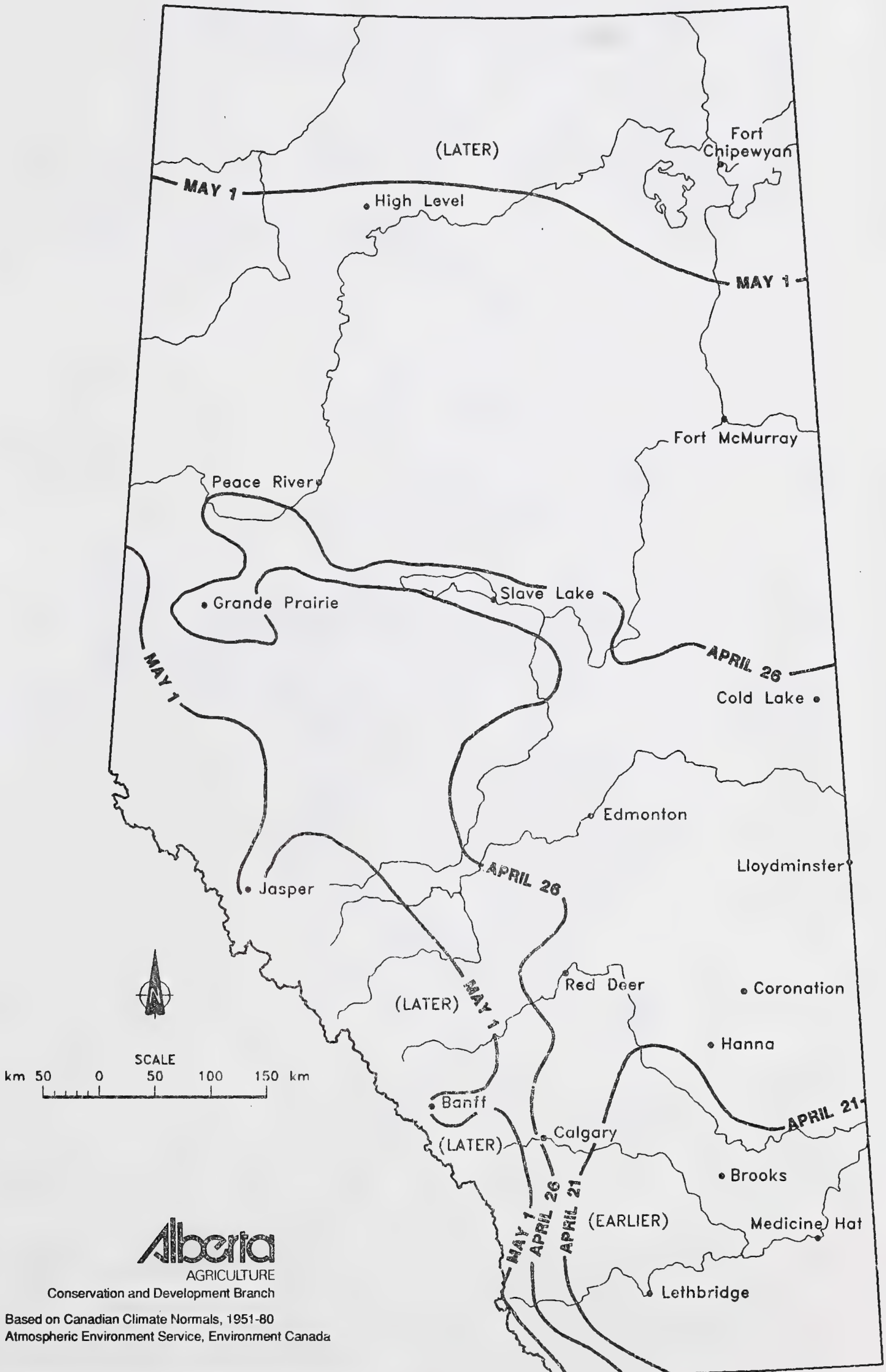
Map 13. Date of last spring frost (0°C) 1951 - 80



Map 14. Date of first fall frost (0°C) 1951 - 80



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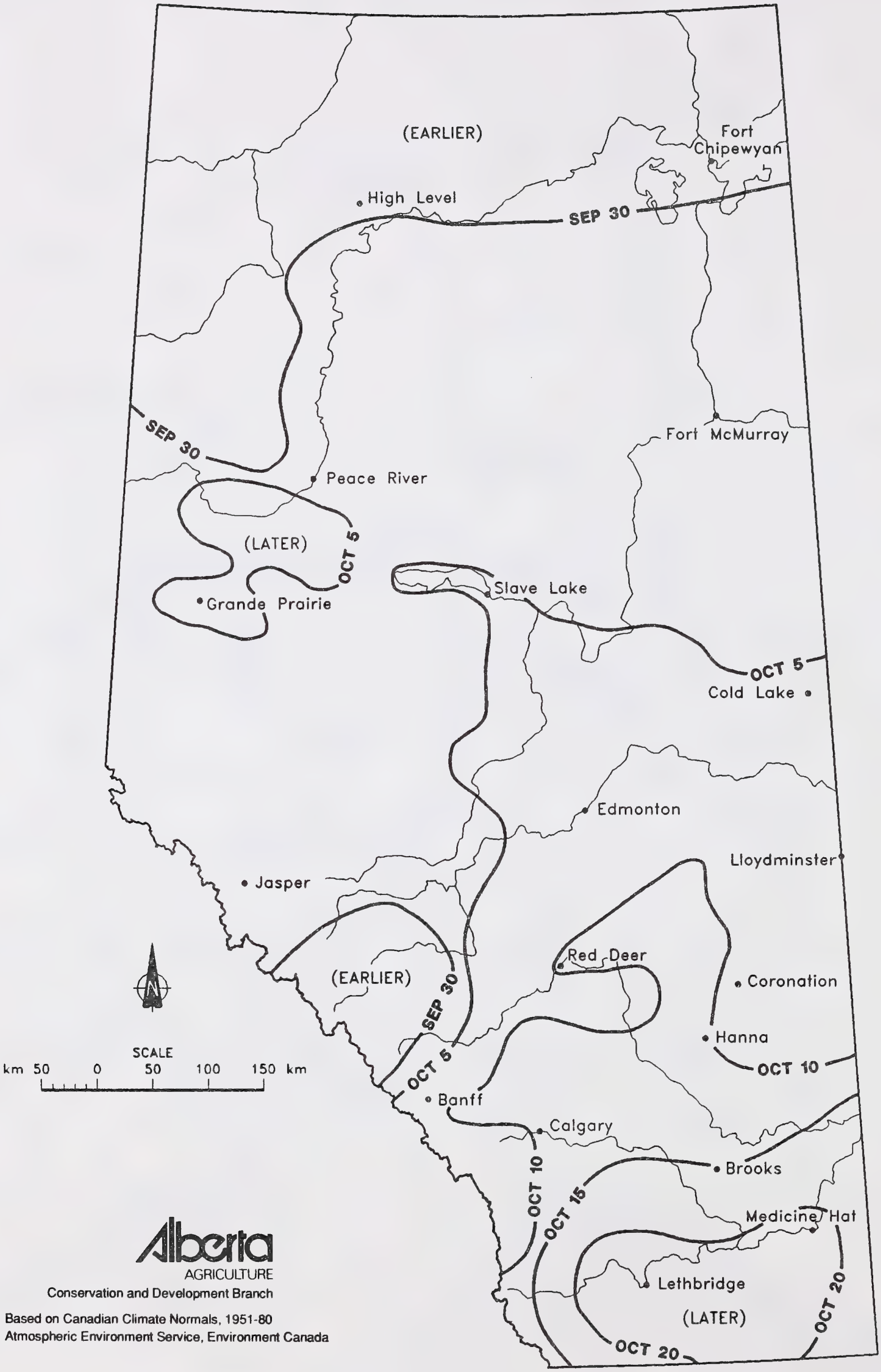
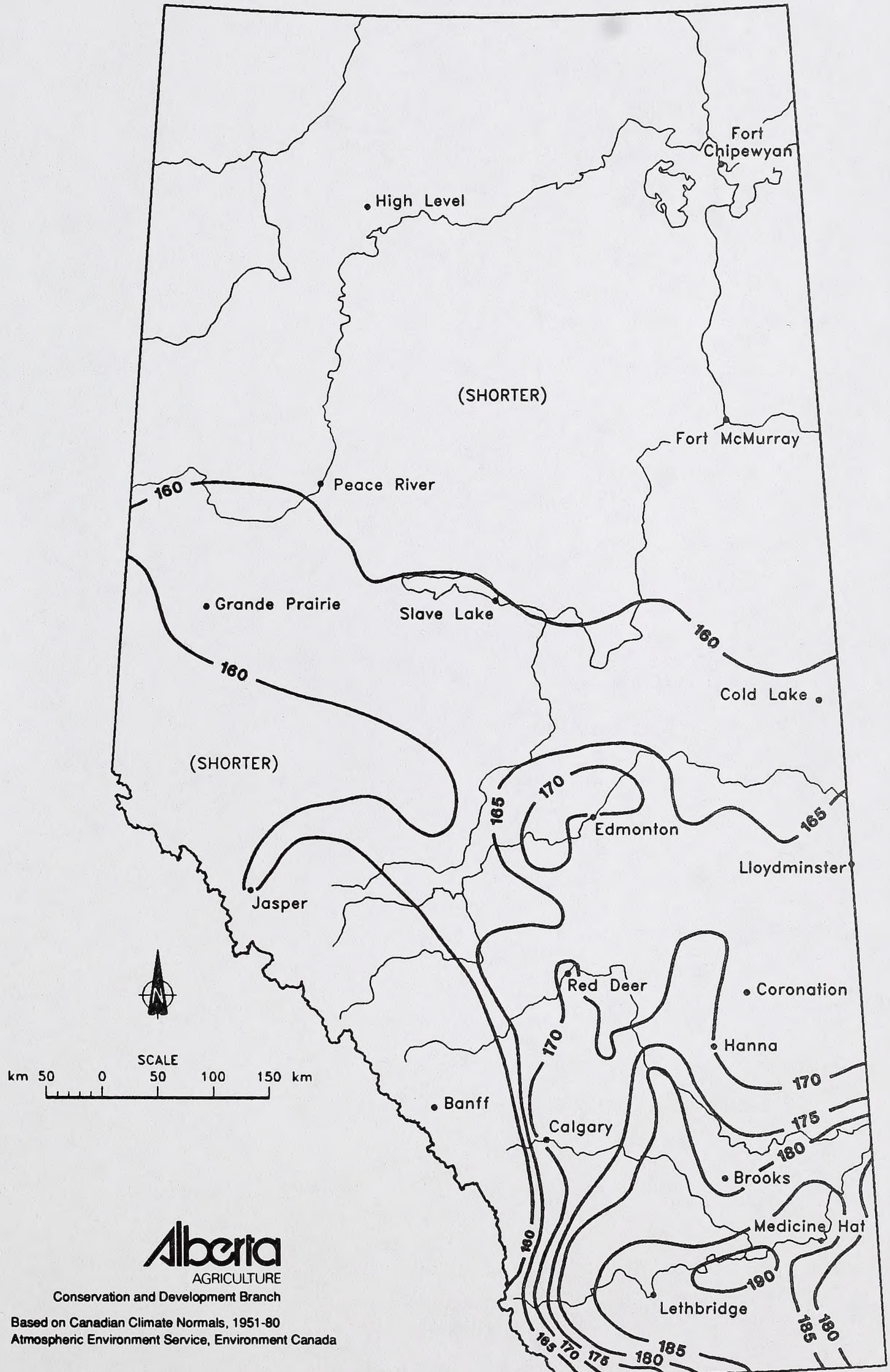
Map 15. Date of start of growing season (5°C) 1951 - 80



Map 16. Date of end of growing season (5°C) 1951 - 80



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Map 17. Length of growing season (days above 5°C) 1951 - 80